DOCUMENT RESUME

ED 308 680 EC 220 553

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TITLE Neurolinguistic Deficits and the Left Hemisphere in the Reading Disabled.
PUB DATE 9 Feb 89
NOTE 14p.; Paper presented at the Annual Meeting of the International Neuropsychological Society (17th, Vancouver, B.C., February 8-11, 1989).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Evaluative/Feasibility (142)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Attention Control; Auditory Perception; *Brain Hemisphere Functions; Comparative Analysis; *Educational Diagnosis; Elementary Education; Listening Comprehension Tests; *Neurolinguistics; *Phonology; *Reading Difficulties
IDENTIFIERS *Dichotic Listening

ABSTRACT

This study addressed the left hemisphere deficiency hypothesis, associated with reading disability, by accounting for attention and examining the relationship between dichotic listening results and neuropsychological deficits. Twenty reading-disabled (RD) and 20 non-reading-disabled (NRD) boys, aged 8-12, were administered the Verbal Dichotic Listening Task, the Non Verbal Dichotic Listening Task, the Lindamood Auditory Conceptual Test (LAC), and the Luria Nebraska Neuropsychological Battery-Childrens Revision (LNNB-CR). Results showed that RD children performed significantly more poorly than NRD children on: tests designed to measure overall "neurological involvement"; scales believed to tap predominantly left hemispheric processes, including the LNNB-CR Writing, Expressive Language, and Reading scales; the LAC, a test of phonemic segmentation; and the Left Sensorimotor scale, a scale which presumably taps left hemispheric sensory and motor functions. RD children performed equivalently to NRD children on the right hemispheric Visual scale. While RD children exhibited a similar left ear advantage for dichotic words as NRD children, they performed more poorly with both left and right ears. These data suggest that RD boys have problems with specific, predominantly left hemisphere-controlled functions, some of which are critical to reading. (JDD)

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Neurolinguistic Deficits and the Left Hemisphere in the Reading Disabled

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International Neuropsychological Society
Annual Meetings
Vancouver, B.C., CANADA

February 9, 1989

EC 220553

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Several investigators have attempted to study neuropsychological functioning and hemispheric processing of those with reading disorders (RD). A substantial body of evidence suggests that the information processing capacities of the left cerebral hemisphere somehow inefficient in the RD population. Chief among the neuropsychological dysfunctions found in these studies are the lack of ability to phonetically segment and code the letters they see, problems hypothetically associated with the left hemisphere (Jorm, 1979). This same dysfunction or inefficiency of the left hemisphere has been blamed for the atypical results often found in dichotic listening (DL) studies of the RD population. While the sum of the research is inconclusive, several investigators have shown a lessened right ear advantage (REA) in the RD / Learning Disabled population (Lewandowski and Kobus, 1985; Obrzut, Obrzut, Bryden, and Bartel, 1985). In addition to a left hemisphere deficiency hypothesis (for processing verbal stimuli) some authors using an information processing perspective have blamed attention problems for RD children's atypical DL performance (Obrzut, Hynd, Obrzut, and Pirozzolo, 1981). However, despite the fact that attentional factors seem to influence the DL performance of children, (Obrzut, et al, 1985), attention does not seem to account for the wide variety of findings, nor for the lack of asymmetry in other areas (i.e., handedness). It is possible that the linguistic nature of DL tasks produces the lowered performance of RD subjects, particularly for stimuli targeted for the right ear / left hemisphere. Possibly neuropsychological deficits, phonemic processing problems, and atypical lateralization all relate to left hemisphere inefficiency as suggested by Geschwind and Galaburda (1985). However, the connection between atypical language lateralization, phonemic processing problems, and other neuropsychological deficits, all implicating the left hemisphere, has not been comprehensively investigated. The purpose of this study was to attempt to address the left hemisphere deficiency hypothesis associated with reading disability by accounting for attention and examining the relationship between DL results and neuropsychological deficits, including linguistic function.

Method

Twenty RD and twenty non-reading disabled (NRD) right handed boys between the ages of 8 - 12 served as subjects. The twenty RD males were all previously independently identified by a qualified diagnostic team as RD, and eligible for remedial services, had no indication of physical, emotional, or cultural interferences which could affect reading ability. They also had Full Scale IQs at least in the average range on the WISC-R and neither Verbal nor Performance WISC-R scale scores below 82, to rule out severe generalized verbal or non-verbal dysfunctions. The RD children also scored at least 1 and 1/2 years below expected grade equivalent (based on chronological age) on either the Woodcock Reading Mastery Test (grades 1 - 3), or the Reading section of the Woodcock Johnson Psychoeducational Battery (grades 4 and above). The 20 NRD boys were matched for chronological age with the RD children, had full scale IQs within the average range, and were selected as average readers, based upon three criteria: teacher report, group, and individual school-based test results.

Instruments

The Verbal Dichotic Listening Task was a fused rhymed words test which consists of 60 trials of 15 different pairs of monosyllabic words presented dichotically, each word pair differing only in its initial consonant. The Non Verbal Dichotic Listening Task consists of a series of 80 trials of randomized melodies. On each trial a dichotic pair is played, followed by one binaural melody. The latter melody is identical to the left channel melody on 20 sets of trials and the right channel melody on another 20 trial, and does not match either melody of the dichotic pair on the remaining 40 trials. The child provides a nod response if he detected a match in melodies, or a head shake (no) response of he did not detect a match. On the Lindamood Auditory Conceptual Test (LAC) the child demonstrates an awareness of the differences, placement, and order of phonemic segments in speech. The LAC is standardized on a population of children grades K to 12, therefore has norms applicable to the subjects' age level, and the LAC also uses nonsense syllables which circumvents the possible confounding factor of knowledge of how words are spelled on segmenting ability (Ehri, 1984). The Luria Nebraska Neuropsychological Battery-Childrens Revision includes a wide assortment of scales, including a clinical measure of laterality, the Left and Right Sensorimotor Scales, a general index of neurological dysfunction, the Pathognomonic Scale, Expressive Language and Receptive Speech, Memory, Intellectual, Rhythm, Tactile, Motor,

Visual, Reading, Writing, and Arithmetic Scales. To attempt to control for attention, during dichotic listening a "game show" strategy was incorporated. Children received rewards for good attention and maintaining central fixation. Performance feedback was given at specified times.

Results

Table 1 provides means and standard deviations for chronological age, expected and actual reading level, Verbal, Performance, and Full Scale WISC-R IQ Scores. The only significant difference between the groups on these variables was in reading performance, as would be expected.

The LHD hypothesis was tested in part by comparing groups on the LNNBCR, Left Sensorimotor, Language Expression, Speech Reception, Reading, and Writing Scales. The group mean performances on these and all other scales are listed in Table 2.

The LHD hypothesis suggested that RD children would perform poorer on left hemisphere / left sensorimotor functions. A Group (RD, NRD) by Scale (Left, Right Sensorimotor) ANOVA for matched groups revealed that RD children scored significantly higher (less well) on both scales, and in particular, the Left Sensorimotor scale, $F(1,19) = 16.20$, $p < .0001$. No significant Group by Scale interaction was present $F(1,19) = 1.54$, $p = .22$. Within the RD group, the left Sensorimotor Scale was higher (poor performance) than the Right Sensorimotor Scale at a level approaching statistical significance $F(1,19) = 7.11$, $p. = .11$. The mean of the Right Sensorimotor scale was slightly, but not significantly higher for the RD versus NRD group. To further test the extent of possible right hemisphere involvement, groups were compared on the Visual scale (Table 2), which predominantly taps right hemisphere functioning. Results indicated no significant group difference, and no RD child with a performance in the "clinical" range. Table 3 provides the means and ANOVA results associated with raw performance on dichotic words. A 2x2 (Group X Ear) ANOVA with groups matched for age indicated that both the Group and Ear differences were significant, but the Group by Ear interaction was not significant. As predicted, the RD group performed inferior to the NRD group on both ears, yet exhibited the same right ear advantage.

The mean performance scores on dichotic melodies and ANOVA results are shown in Table 4. Left ear "same" is the number of correct responses for the left ear. Right ear "same" is the number of correct responses for the right ear. "Different" is the number of correct responses when neither ear should be identified as "same". Since "different" scores have no meaning in interpreting laterality, but are an important indication of the accuracy of the child's response, these scores were placed in a separate one way (Group x "Different" score) ANOVA which indicated no significant effects. Similarly, results of the 2x2 ANOVA (Group X Ear) indicated that as hypothesized, both groups performed equivalently on dichotic melodies. Unexpectedly however, neither group exhibited a significant left ear effect, although seventeen RD and 9 NRD children exhibited higher left ear scores.

On the Lindamood Test of Auditory Conceptualization RD children obtained a mean score of 50.1 (SD 16.60), and range of 25-76, and NRD children attained a mean of 89.85 SD 8.01) and range of 79-100. The group difference on the LAC was highly significant, $F(1,19) = 105.6$, $p<.0001$, even though the RD children were considered only adequate readers, similar in IQ, and were matched to RD children by age. Surprisingly, there was perfect separation between the two groups of scores.

Table 5 provides the correlation matrix for key variables associated with each measure. It is noteworthy that many tests associated with left hemispheric processing are at least moderately correlated with other tests associated with left hemispheric processing and less correlated with right hemispheric tasks. The right ear dichotic words score (a phonemic task) is at least moderately correlated (range .40-.45) with left ear dichotic words and the LAC. It is not highly correlated with left ear melodies, Tactile, or visual scales (range -.21 to .02). The LAC is at least moderately correlated (range 0.45-.85) with left and right ear dichotic words, and most LNNB-CR scores, including the Left (but not Right) Sensorimotor Scale. It is weakly correlated with left or right ear dichotic melodies, Visual, and Tactile scales. The Left Sensorimotor scale is at least moderately correlated (range .40 to .68) with left ear dichotic words, LAC, Motor, Rhythm, Tactile, Expressive Speech, Reading, Writing, Arithmetic, and Memory. It is not moderately correlated

(range .03 to .37) with Left or Right dichotic melodies, Visual, or Receptive Speech on the LNNB-CR. These data provide convergent validity as to strong relationships among left or right hemispheric tasks and weak relationships between them.

Discussion

The principal findings of this study are:

1. RD children performed significantly poorer than NRD children on LNNB-CR tests designed to measure overall "neurological involvement".
2. RD children performed poorer than NRD children on scales believed to tap predominantly left hemispheric processes, including the Writing, Expressive Language, and Reading scales.
3. RD children also performed poorer that NRD children on the Left Sensorimotor scale, a scale which presumably taps left hemispheric sensory and motor functions.
4. RD children performed equivalent to NRD children on the right hemispheric Visual scale.
5. While RD children exhibited a similar left ear advantage for dichotic words as NRD children, they performed poorer with both left and right ears.
6. RD children performed significantly poorer on a test of phonemic segmentation: the LAC.
7. Tests typically associated with left hemispheric processing (such as verbal dichotic listening, LAC, Left Sensorimotor scales) tended to be at least moderately related to each other. They also tended to be less less to "right hemispheric" tests such as dichotic melodies, Right Sensorimotor and Visual scales.

In summary, the interrelationships between laterality and cognitive variables strengthen the support for evidence of left hemispheric information processing dysfunction in RD children. Although RD children may exhibit both verbal and nonverbal deficits, specific left hemispheric processing deficits (such as phonemic analysis) may be a major underlying factor in reading disability. These findings do not support reading and laterality models such as Orton's (1937) or Witelson's (1977) which attribute some form of deviant cerebral organization or "incomplete cerebral dominance"as the cause of a reading disability. Geschwind (1985) presents the notion that RD children's left hemispheres are "deficient" in processing information required in reading, a notion which appears to be well supported by the findings of this study. Even controlling for attention, left hemishperic performance deficiencies appear to exist in the RD group, consistent with Geschwind's speculations. This study suggests, that even when attention is presumably fully maximized in both hemispheres through maintaining central visual fixation, and by giving extra cues and reinforcement, phonological processing continues to be a salient deficit. Therefore, attentional problems, though important in RD children, in themselves do not explain these data. More recently Hisckock and Kinsbourne (1987) suggested an approach combining hemispheric activation and a form of the left hemisphere deficiency hypothesis. This notion is supported by these findings.

More research on the neuropsychology of RD is needed to further determine the implicated cognitive subcomponents of reading disorder. RD children are experiencing difficulties with specific subprocesses which are crucial to the reading task itself. Phonemic analysis may be only one of these subprocesses. Others may be verbal or non-verbal sequencing, and/or visuospatial analysis. In order to best identify and aid RD children, these subprocesses must be identified for various subgroups of RD children. But in order to properly identify these subprocesses, it is necessary to gain knowledge of how mechanisms such as attention and effort impact upon them. The use of current models of information processing and neuropsychology may aid in the attempt to untangle the complexities of reading disability.

Suggested Readings:

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Swanson, H. & Obrzut, J. (1985). Learning Disabled Readers' Recall as a Function of Distinctive Encoding, Hemispheric Processing, and Selective Attention. *Journal of Learning Disabilities, 18,* 409-18.

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Table 1

Descriptive Data of Each Group for Age; IQ, and Reading Level

Variable	Group			
	RD		NRD	
	M	SD	M	SD
Age	10.25	1.4	10.18	1.3
VIQ	95.8	5.9	103.9	7.6
PIQ	104.5	9.4	105.6	8.6
FSIQ	99.3	5.9	104.7	6.9
Expected (G.E.)	5-2	1-5	5-1	1-3
Actual (G.E.)	2-8 [a]	1-0 [b]	5-3	1-7

[a]RD Actual reading performance is significantly below Expected performance ($p<.01$)

[b]NRD significantly greater than RD Actual reading performance ($p<.01$)

Table 2

Group Mean Scores and Comparisons on the LNNB-CR Scales

Scale	RD	NRD	Signif
General			
Intelligence	58.75	45.75	.0007
Memory	62.94	49.4	.0001
Rhythm	69.3	48.3	.0001
Pathognomic	75.05	47.25	.0000
Primarily Left Hem			
Expressive Language	74.0	45.1	.0001
Receptive Speech	62.65	47.15	.0001
Reading	76.45	41.75	.0001
Writing	79.5	44.2	.0001
Left Sensorimotor	61.25	49.9	.002
Motor	62.55	47.7	.0001
Arithmetic	67.6	45.0	.0001
Primarily Right Hem.			
Visual	50.46	44.5	NS
Right Sensorimotor	51.8	45.6	NS

Table 3

Mean Raw Scores Per Group on the Dichotic Words Task

Ear[a]	Group[b]			
	RD		NRD	
	M	SD	M	SD
Left	23.2[c]	2.79	27.4[c]	5.3
Right	27.7[c]	3.6	31.8[c]	5.5

[a]Main effect for ear was significant, $F(1,19)=26.7$, $p<.0001$

[b]Main effect for group was significant, $F(1,19)=18.4$, $p<.0001$

[c]Group X Ear interaction was not significant, $F<1.0$

Table 4

Mean Raw Scores Per Group on the Dichotic Melodies Task

Ear[a]	Group			
	RD		NRD	
	M	SD	M	SD
Left	13.8	2.7	13.9	2.7
Right	11.9	2.9	14.0	3.2
"Different"[b]	22.7	6.0	22.1	7.5

[a]Group X Ear ANOVA yielded no significant effects or interaction

[b]One Way ANOVA between groups was not significant

Table 5

Intercorrelations Among Specific Dependent Measures*

	LAC	DW-R	DW-L	DM-R	DM-L	Rt Sens	Lt Sens	Rdg	Wrtng	Exp Lang	Rec Lang	Visual	Motor	Tactile
Phonemic	-.81*	-.43*	-.41*	-.44*	.26	.40*	.44*	.96*	.89*	.80*	.65*	.38	.67*	.21
LAC		.42*	.41*	.21*	.01*	-.28*	-.46*	-.81*	-.84*	-.76*	-.72*	-.51*	-.66*	-.22
Dichotic Word-R			.52*	.12*	-.21*	-.27*	-.25*	-.37*	-.33*	-.33*	-.25*	-.22*	-.35*	.13*
D W-L				.38	.38	-.30	-.35*	-.42*	-.40*	-.45*	-.17	-.30	-.52	-.08
Dichotic Melody-R					.51	-.26	-.03*	-.45*	-.37	-.32	-.16	-.13	-.17	-.01
D M-L						-.10	-.06*	-.22	-.15	-.11	-.11	.10	-.06	.09
Rt Sensory							.67*	.45*	.28*	.43*	.29*	.41*	.54*	.52*
Lt Sensory								.40*	.44*	.40*	.36	.21	.68*	.63
Reading									.84	.85	.62	.45*	.66*	.23
Writing										.71*	.65*	.40*	.59*	.22
Express. Lang.											.69*	.44*	.67*	.21
Recpt. Lang												.44*	.60*	.21
Visual													.33	.11
Motor														.43*

*Correlations of primary interest are highlighted

ABSTRACT

20 READING DISABLED (RD) AND 20 NON READING DISABLED (NRD) BOYS WERE TESTED VIA DICHOTIC WORD AND MELODY TASKS, THE LURIA-NEBRASKA NEUROPSYCHOLOGICAL BATTERY-CHILDRENS REVISION (LNNB-CR) AND THE LINDAMOOD TEST OF AUDITORY CONCEPTUALIZATION (LAC). BOTH GROUPS EXHIBITED RIGHT EAR/ LEFT HEMISPHERE SUPERIORITY FOR DICHOTIC WORDS. HOWEVER, THE RD BOYS IDENTIFIED FEWER WORDS OVERALL. THE RD BOYS PERFORMED POORER THAN NRD BOYS ON PRESUMED "LEFT HEMISPHERE" TASKS (I.E., RIGHT SIDE OF BODY, PHONEMIC AND LANGUAGE), AND EQUIVALENTLY ON "RIGHT HEMISPHERE" TASKS (I.E., LEFT SIDE OF BODY, DICHOTIC MELODIES AND VISUAL SCALE). THESE DATA SUGGEST THAT RD BOYS DISPLAY SIMILAR PATTERNS OF HEMISPHERIC SPECIALIZATION, YET HAVE PROBLEMS WITH SPECIFIC, PREDOMINATELY LEFT HEMISPHERE-CONTROLLED FUNCTIONS, SOME OF WHICH ARE CRITICAL TO READING.